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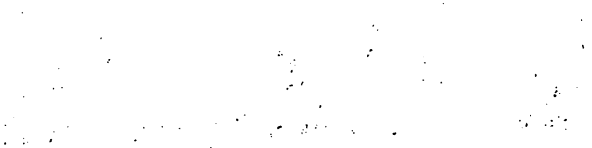
Stevens

# LIGHTHOUSES.



BELL ROCK LIGHTHOUSE.

# LIGHTHOUSES

BY

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Treatise on the Application of Marine Surveying and Hydrometry to Civil Engineering; Remarks on the Improvement of Tidal Rivers;
Treatise on Canal and River Engineering;
&c. &c. &c.

*FROM 'GOOD WORDS.'*

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# PREFATORY NOTE.

THE following Papers are republished with the sanction of the Author, and of the Proprietors of "Good Words," for which Periodical they were written.

EDINBURGH, *August* 1864.

# INTRODUCTION.

EVERY native of our sea-girt kingdom ought to feel an interest in the questions—What do we owe to our lighthouses? and what would our country be without them?—but we suspect that, from lack of information, these questions are not viewed with the attention which they demand.

A stormy wind may rudely drift the sleet against our windows and disturb our rest; and perhaps our sympathies may be awakened for the men who patrol our dark streets as guardians of our property: but seldom in those dismal nights do our thoughts extend to the solitary outposts of our land, where, confined to the narrow cabin of a lightship, or watching in towers

perched on bleak headlands or sunken rocks, the true guardians of this country's naval greatness keep their quiet and unostentatious vigil unthought of, because remote and unknown.

What, indeed, would our country be without its lighthouses?—A rugged inhospitable land truly. Our shores no coaster could safely navigate, and no oversea vessel could confidently approach; while ever and anon, as in early times, our sea-beaches would be strewed with the timbers of stranded vessels, and the bodies of their ill-fated crews? So common, indeed, were such calamities at the beginning of the present century, that the inhabitants of our Northern Isles regarded shipwrecks with indifference, if not with real complacency. It had, indeed, become proverbial to observe, "that if wrecks were to happen, they might as well be sent to their poor islands as anywhere else;" and, acting on

this convenient principle, the natives unsparingly availed themselves of the "providential" supplies thus laid to their hands, occasionally using claret to their barley-meal porridge, and even fencing their fields with Honduras mahogany, shipped from its native forests to grace the interiors of our palatial mansions! But the introduction of the lighthouse system put an end to this wholesale and indiscriminate consignment of property to the hands of the "wrecker;" and at a later period, on complaining to an Orcadian pilot of the badness of his sails, his reply was, "Had it been God's will that you came na' here wi' your lights we might a' had better sails to our boats and more o' other things."

What we owe to our lighthouse system is well exemplified in the Bell or Inchcape Rock. Even in early times this reef was so great a terror to mariners, that a certain Abbot of Aberbrothock, as chronicled in

Southey's well-known lines, placed on it a bell, moved by the restless waves :

> "As a buoy in the storm it floated and swung,
> And over the waves its warning rung."

And, as tradition has it, the pirate, Sir Ralph the Rover, was himself wrecked on that very reef from which he had, with murderous hands, removed the danger-signal of the pious monk. But leaving tradition and coming to facts, we learn that when Robert Stevenson made his first landing on the Bell Rock, in the year 1800, he found lodged in almost every crevice sad proofs of the dismal tragedies which had been enacted on that treacherous spot. These melancholy evidences of death consisted of bayonets, musket-balls, and innumerable fragments of iron. All more perishable materials had been swept away, and a silver shoe-buckle was the only vestige of wearing-apparel to commemorate the *graves of* many who doubtless drew their

last breath among the boiling surges of the Inchcape Rock. Nor was it only on the rock itself, unbeaconed by day, and unlighted by night, that vessels were driven to pieces and lost. Many ships were stranded on the neighbouring shores in trying to avoid the track, where, buried in the waves and concealed by their glassy covering, the dreaded hidden danger lay. Mr. Stevenson records a melancholy example of this, which happened in 1799, when a three-days' gale from the south-east drove from their moorings, in the Downs and Yarmouth Roads, and from their southward courses, a large fleet of vessels. Borne north by the gale, these ships might easily have reached the anchorage of the Firth of Forth, for which the wind was fair; but night came on, and fearing the Bell Rock, their ill-fated pilots resolved to keep at sea, and so escape *its dangers*, but driven before the

pitiless storm in a dark December night they lost all knowledge of their position and were helplessly wrecked—two of them on the Bell Rock, and about seventy on the eastern shores of Scotland, where, sad to tell, many of their brave crews perished.

"This fatal catastrophe," says Mr. Stevenson, in a report to the Commissioners of Northern Lighthouses, "is more to be lamented, when it is considered that a light upon the Bell Rock, by opening a way to a place of safety, would infallibly have been the means of preventing such a calamity." That Mr. Stevenson was correct in offering this opinion, is proved by the fact that not a single vessel has been lost upon that dreaded rock since the completion of the lighthouse in 1811—a period of upwards of half a century! The reef which was once a terror to mariners is now, happily, their comfort; the danger which they *formerly dreaded* they now confidently ap-

proach, well knowing that so long as they can keep their vessels dodging "off and on" in sight of its everchanging white and red signal lights they are in safety: though the sky be moonless and starless, they know that in the Bell Rock they have a constant leading star, and that trusting to its guidance in the darkness, they can run for the Firths of Forth or Tay when daylight dawns. Sir Walter Scott, on his visit to the Bell Rock in 1814, gave happy expression to the value of its midnight cheering beams in the following well-known lines, in which the lighthouse tells its own tale:—

"Far in the bosom of the deep,
O'er these wild shelves my watch I keep,
A ruddy gem of changeful light
Bound on the dusky brow of night.
The seaman bids my lustre hail,
And scorns to strike his timorous sail."

What has been said of the Bell Rock applies, in at least some degree, to every light *upon the coast*; and although, perhaps,

we have now happily no island-farms fenced with mahogany, and no islanders using wine instead of milk, yet it cannot be denied that there are some dark corners where lights are still required, and where similar happy results would follow their erection. Ours is a maritime country; the extension of its lighthouse system is the safeguard of its navy and its commerce; and the extinction of the hope-inspiring beacon-lights on our coasts—were such an idea conceivable—would fill our sailors with despair, and cause a dismal night of national darkness and horror.

Of the early history of lighthouses little or nothing is known. A few obscure notices of the Colossus of Rhodes and the Pharos of Alexandria, in the writings of ancient authors, seem to comprehend all our information on the subject; but what was the origin, and what was the fate of these ancient structures—how they were built, and in *what way* they were lighted, we do not

know. Our knowledge of modern lighthouses, extending back to the fifteenth century, is, however more exact, and to us more interesting and important. The Tour de Cordouan at the mouth of the River Garonne in the Bay of Biscay, of which there is a view on the next page, was finished in the year 1610, and, *revolutionised* by modern improvements, it still maintains its character as one of the finest lighthouses in the world. Winstanley's timber structure on the Eddystone was lighted in 1698, and was swept away in 1703, when, unhappily, he and all his men, who had been making some repairs on the building, perished. Rudyerd's timber tower, erected on the same rock, was burned down in 1755, and the present lighthouse erected by Smeaton was lighted in 1759. The earliest light in Scotland is supposed to have been the open coalfire of the Isle of May, to be *afterwards noticed;* but the establishment

FIG. 1. TOUR DE CORDOUAN.

of public lights in Scotland dates from 1786, when a bill, committing the management to the Commissioners of Northern Lighthouses, was passed; and the first light exhibited by them was Kinnairdhead, lighted in 1787, from the designs of Mr. Smith, their first engineer. The Ballast Board of Dublin, to whom are entrusted the management of the Irish Lights, was incorporated by Act of Parliament in the same year.

The construction and illumination of lighthouses have undergone vast improvements since the commencement of the present century; and Britain has had no small share in furthering the development of this important branch of civil engineering. We owe to France, it is true, Fresnel's Dioptric Apparatus, but Britain is pre-eminent for her lighthouse towers. The Eddystone of Smeaton, the Bell Rock of Robert Stevenson, and, in more modern times, Alan Stevenson's *Skerryvore* and James Walker's

Bishop's Rock Lighthouses, are structures of which a writer in the "Quarterly Review" has truly said: "Taken altogether, they are perhaps the most perfect specimens of modern architecture which exist. Tall and graceful as the minar of an Eastern mosque, they possess far more solidity and beauty of construction; and, in addition to this, their form is as appropriate to the purposes for which it was designed as anything ever done by the Greeks, and consequently meets the requirements of good architecture quite as much as a column of the Parthenon."

Assuming that our readers are ready to admit the importance of the subject which we have undertaken to expound, we shall endeavour, in as plain and untechnical phraseology as possible, to give some account of the *construction*, *illumination*, and *management* of these useful and interesting structures; and if our illustrations are taken chiefly from Scottish lighthouses,

we trust our readers will understand that it is because we happen to know most about the works on our northern shores, and because it is to the Commissioner of Northern Lighthouses that we are indebted for most of our published information on lighthouse engineering.

## Construction of Lighthouses.

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Lighthouses are almost invariably constructed on sites of difficult access. Perched on high headlands or remote islands, founded on sunken rocks or shifting sandbanks, in each case the engineer has to accommodate his design to the locality. But as it is impossible, in such a sketch as this, to describe all the structures that have been adopted in carrying out our lighthouse system, we can only give the reader an imperfect idea of some of the most important of them.

The ordinary lighthouse establishments situated on headlands or large islands demand but little notice: they are all constructed after the same fashion—the *illuminating* apparatus, to be afterwards

noticed, being the only exception. They include, of course, a light tower, whose height depends on the elevation of the ground on which it is built, and the range from which the light has to be seen, with a dwelling for the keepers and their families immediately adjoining. These buildings, in order to meet the wants of the mariner, are often placed on the very brink of a precipice, and always on the most exposed place that can be found. In selecting the site for a comfortable house, we naturally seek for *shelter;* but in determining the best position for a lighthouse the engineer must generally adopt the most exposed and inhospitable bit of land he can find, and *there* he plants his tower, defying the elements, and despising the shelter which all other mortals seek in fixing their abode. It is absolutely necessary, therefore, that all parts of the work should be made in the most substantial manner; and in order to

repel rain, and sleet, and snow, and damp, the houses in many exposed places are built with an internal lining, so as to form a double wall, and are roofed with lead instead of slates. Some of these land-

FIG. 2. NOSSHEAD LIGHTHOUSE.

stations are far removed from any inhabited dwelling; and the engineer's first duty is to construct a road at great cost over bleak mountains and deep morasses, before a single ton of material can be laid down at the site of the projected work. It will be easily understood, therefore, that a lighthouse establishment, from

its exposure and isolation, must, even in *ordinary* cases, be a work involving *no ordinary* amount of expense. The accompanying woodcut, showing Nosshead Lighthouse, in Caithness, will serve to convey to the reader an idea of these ordinary establishments.

In other cases the towers are built on detached rocky eminences, which afford no space for accommodating the keepers' families, and a site for their dwellings must be sought on the adjoining coast. Here the lighthouse engineer has not only to contend with all the difficulties of a situation exposed to wind and rain, but he has the more formidable dangers of the sea to combat; for on many of these outlying isolated rocks, surrounded by rapid tideways, the waves are seldom at rest, and often break with great force. This class of stations may be fitly represented by the North Unst Lighthouse off

the north coast of Shetland, which we select as being the most northern point of Her Majesty's British dominions. The North Unst Tower is built on an outlying rock of a conical form, called a "stack," which rises to the height of nearly 200 feet above the sea. Towards the north its face is nearly perpendicular, and exposed to the full "*fetch*" of the Northern Ocean. Its southern face is a steep rocky slope, which, previous to the cutting of steps on its surface, could only be scaled with great difficulty. The top of the rock affords little more area than is sufficient for the site of the lighthouse. The tower is 50 feet in height, and contains the lightroom, sleeping-room, kitchen, and provision store. The base of the tower is surrounded by a semicircular building, containing the oil, coal, and water stores. There is only one part of the rock at which a landing can be effected, and that of course only in favourable weather. The dwelling-

houses for the families of the four light-keepers are built on the Island of Unst, in a creek called Burra Fiord, about four miles from the lighthouse. The first light on this rock was shown from a temporary tower, erected in 1854, at the suggestion of the Admiralty, for the benefit of the North Sea Squadron, then engaged in prosecuting the Russian war. The Government deemed it advisable to provide certain lights before winter set in, and only a few months remained to make all the necessary preparations for indicating to our navy the rugged shores of Northern Shetland. The "Pharos" steamer left Glasgow, with the workmen and temporary lighthouse and dwellings, on the 31st July, and the light was exhibited on the 11th October; and when it is considered that the whole of the materials and stores (consisting of water, cement, lime, coal, iron-work, glass, and provisions, and weighing *upwards of* 120 tons) had to be landed on

an exposed rock, and carried up to the top in small quantities on the backs of labourers, it will be seen that the exertions of Mr. Brebner, who acted as resident engineer, and of Mr. Watt, who took charge of the landing department, were in the highest degree praiseworthy. Even with the fine weather that prevailed, the landings were latterly very difficult, and could only be accomplished by lashing ropes to the various articles and lowering them out of the landing boats, and thereafter hauling them to the edge of the rock. But notwithstanding all untoward circumstances, the whole process of transporting the materials to the top of the rock, and erecting the lighthouse, was accomplished in the wonderfully short space of twenty-six days. The temporary houses were of iron, surrounded by a casing of rubble masonry set in cement. Seeing that these temporary buildings were elevated nearly 200 feet above the sea, it was hardly to be

expected that they should have had anything but the wind and the rain to withstand; but the succeeding winter months revealed a very different and unlooked-for state of matters. From the 1st to the 4th December, the North of Shetland was visited by a severe gale from the north-west. The foreman of the quarriers, who had been left to complete the cutting of the steps in the face of the rock, reported that on the 3d of December the sea began to break over the rock about 9 A.M., and increased in weight until 1 o'clock: several seas thereafter broke heavily on the tower, and one of them burst open the door of the dwelling-house, deluging the whole with water—so that the view we have given in the woodcut does not represent the full fury of the waves. Similar storms occurred during the winter; and the seas fell with such violence upon the iron roof of the *dwelling*-house, and on the lantern of the

lighthouse, as to raise fears for the safety of the buildings. An elevation of nearly 200 feet was not sufficient to place these temporary buildings beyond damage from the sea, and in erecting the permanent establishment, it was resolved to raise the light-room 50 feet above the lofty rock on which it stands, so that the seas might pass over without obscuring or endangering the light. The permanent structure, which we have already described, shows a fixed dioptric light of the first order, and was completed in 1858, at a cost, including the shore establishment, of about £32,000.

The most important class of lighthouses is, however, that of which the Eddystone, the Bell Rock, and the Skerryvore are examples. These three works, moreover, are peculiar, as having been executed under the *personal* superintendence of their respective engineers; and we shall give some

brief notices from the interesting published narratives of their construction.

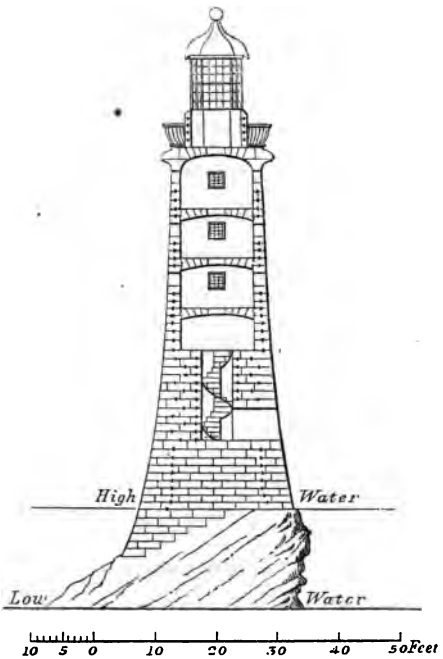


FIG. 4. THE EDDYSTONE LIGHTHOUSE.

The history of the far-famed Eddystone is given in the narrative of Smeaton. We *have already* said that two timber structures

had successively been placed upon the rock and destroyed—one by water, the other by fire; but Smeaton resolved that his work should be of stone, so as to defy both elements; and after the lapse of more than a century it still stands at the head of engineering triumphs. The first stone of this remarkable building was laid in June 1757, and the last in August 1759—the whole being completed in two years. The tower is 68 feet in height and 26 feet in diameter at the level of the first entire course. The building is founded on a sloping rock, the upper part of which is on the level of high water of spring-tides. The stones composing the work are united by means of stone joggles, dovetailed joints, and oak trenails. Smeaton adopted an arched form for the floors of his building, which rendered it necessary, in order to counteract the outward thrust, to insert *chains embedded* in grooves cut in the

masonry; but Stevenson, in designing the Bell Rock Lighthouse (to be mentioned hereafter), improved on Smeaton's plan, not only as regards the general arrangement of the masonry, but by converting the floors into effective bonds; so that, instead of exerting an outward thrust, they actually tie or bind the outer walls together. In Smeaton's day the subject of lighthouse illumination had scarcely dawned on engineers, for the only light which crowned this masterpiece of his genius was a frame supporting twenty-four candles! Parabolic reflectors were substituted at the beginning of this century, when the Eddystone light came into the possession of the Trinity House.

The engineer of the Bell Rock Lighthouse had all the advantage of Smeaton's earlier experience, and he was ever ready to acknowledge that Smeaton's narrative *must be his* text-book. But there can be

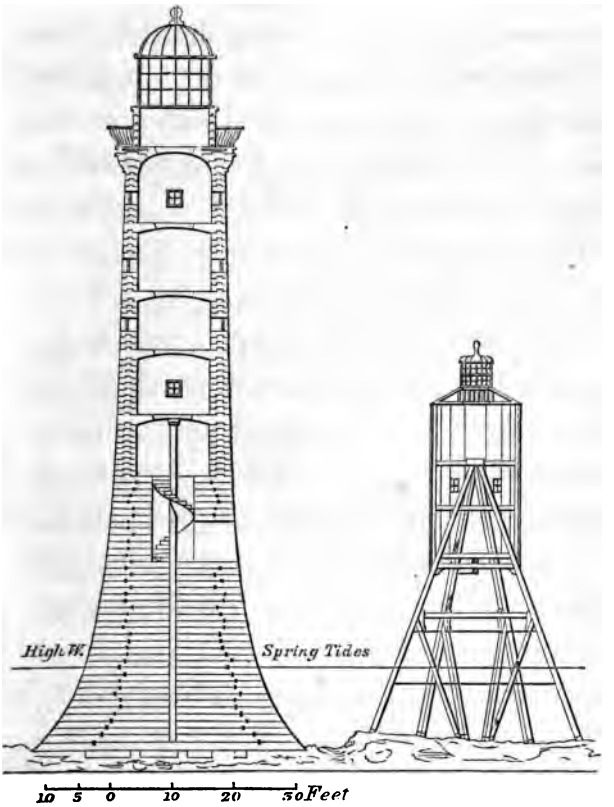


FIG. 5. THE BELL ROCK LIGHTHOUSE.

no doubt whatever that the Bell Rock presented peculiar engineering difficulties. The Eddystone Rock is barely *covered* by

the tide at *high water*, while the Bell Rock is barely *uncovered at low water*. It is only during a low spring tide and with a smooth sea that a landing can be made, and to show the difficulties of the situation, it may be stated that during the whole of the first season of 1807 the aggregate time of low-water work, caught by snatches of an hour or two at a tide, did not amount to fourteen days of ten hours! while in 1808 it fell short of four weeks; its surface, in fact, can only be seen at low tides, and it is submerged to the depth of 16 feet at high water. Rudyerd's *timber tower*, which stood for forty-five years on the Eddystone, could not have survived a single winter at the Bell Rock. The conception, therefore, of erecting a stone tower on this low-lying reef, even with the Eddystone as an example, was no less remarkable for its novelty than for its boldness. *Fully* alive to all the special difficulties

of the case as ascertained by careful examination and survey, Robert Stevenson, in 1800, prepared his design for the Bell Rock Lighthouse, adapting it to its *unique* site, and introducing all the improvements of design and arrangement of materials which distinguish it from the Eddystone. His proposal was duly reported to the Northern Lighthouse Board, of which he was engineer, but it was generally received by the public with grave doubts as to its practicability, and still graver doubts as to the possibility of obtaining a loan of money to be risked on so difficult a project. Mr. Stevenson, adhering to his firm belief in the practicability of his design, urged the Board to consult the late Mr. John Rennie, who, after inspecting the rock along with Mr. Stevenson in 1805, concurred in his opinion as to the practicability of erecting a tower of *masonry.* Strengthened with this addi-

tional advice, the Board resolved to embark in what was in some quarters regarded as a Utopian scheme; but thanks to perseverance and engineering skill, the Bell Rock Lighthouse was, after five years' labour, successfully completed by Mr. Stevenson in accordance with his design.

At the risk of presenting what may perhaps be not altogether new to some of our readers, we shall, as illustrating the peculiar difficulties of this class of engineering works, give a few extracts from Mr. Stevenson's "Account of the Bell Rock Lighthouse," which has not inaptly been styled the Robinson Crusoe of engineering literature.

During the first two seasons, the engineer and workmen lived in a floating lightship, moored about three miles off the rock, and exposed to the full fury of the Northern Sea and German Ocean. Many *a heavy* storm they weathered, and the

following passage gives as lively a picture of a gale at sea as we ever remember to have met with.

"About two o'clock P.M. a great alarm was given throughout the ship, from the effects of a very heavy sea which struck her, and almost filled the waist, pouring down into the berths below, through every chink and crevice of the hatches and sky-lights. From the motion of the vessel being thus suddenly deadened, or checked, and from the flowing in of the water above, it is believed there was not an individual on board who did not think, at the moment, that the vessel had foundered, and was in the act of sinking. The writer could withstand this no longer, and as soon as she again began to range to the sea, he determined to make another effort to get upon deck. It being impossible to open any of the hatches in the fore part of the ship, *in communicating* with the deck, the

watch was changed by passing through the several berths to the companion-stair leading to the quarter-deck. The writer, therefore, made the best of his way aft, and on a second attempt to look out, he succeeded, and saw indeed an astonishing sight. The seas or waves appeared to be 10 or 15 feet in height of unbroken water, and every approaching billow seemed as if it would overwhelm our vessel; but she continued to rise upon the waves, and to fall between the seas in a very wonderful manner. It seemed to be only those seas which caught her in the act of rising which struck her with so much violence, and threw such quantities of water aft. On deck there was only one solitary individual looking out, to give the alarm in the event of the ship breaking from her moorings. The seaman on watch continued only two hours; he had no greatcoat nor overall of any kind, but was simply dressed in his

ordinary jacket and trousers; his hat was tied under his chin with a napkin, and he stood aft the foremast, to which he had lashed himself with a gasket or small rope, round his waist, to prevent his falling upon deck or being washed overboard. Upon deck everything that was movable was out of sight, having either been stowed below previous to the gale, or been washed overboard. Some trifling parts of the quarter boards were damaged by the breach of the sea, and one of the boats upon deck was about one-third full of water, the oyle hole or drain having been accidently stopped up, and part of the gunwale had received considerable injury. Although the previous night had been a very restless one, it had not the effect of inducing sleep in the writer's berth on the succeeding one; for having been so much tossed about in bed during the last thirty hours, he found no easy spot to turn to, and

his body was all sore to the touch, which ill accorded with the unyielding materials with which his bed-place was surrounded.

"Next morning, about eight o'clock, the writer was agreeably surprised to see the scuttle of his cabin skylight removed, and the bright rays of the sun admitted. Although the ship continued to roll excessively, and the sea was still running very high, yet the ordinary business on board seemed to be going forward on deck. It was impossible to steady a telescope, so as to look minutely at the progress of the waves, and trace their breach upon the Bell Rock; but the height to which the cross-running waves rose in sprays, where they met each other, was truly grand, and the continued roar and noise of the sea was very perceptible to the ear. To estimate the height of the sprays at 40 or 50 feet would surely be within the mark. Those of the workmen who were not much

afflicted with sea-sickness came upon deck, and the wetness below being dried up, the cabins were again brought into a habitable state. Every one seemed to meet as if after a long absence, congratulating his neighbour upon the return of good weather. Little could be said as to the comfort of the vessel; but after riding out such a gale, no one felt the least doubt or hesitation as to the safety and good condition of her moorings. The master and mate were extremely anxious, however, to heave in the hempen cable, and see the state of the clinch or iron ring of the chain cable. But the vessel rolled at such a rate that the seamen could not possibly keep their feet at the windlass, nor work the handspokes, though it had been several times attempted since the gale took off.

"About twelve noon, however, the vessel's motion was observed to be considerably less, and the sailors were enabled

to walk upon deck with some degree of freedom. But to the astonishment of every one, it was soon discovered that the floating light was adrift! The windlass was instantly manned, and the men soon gave out that there was no strain upon the cable. The mizzen sail, which was bent for the occasional purpose of making the vessel ride more easily to the tide, was immediately set, and the other sails were also hoisted in a short time, when, in no small consternation, we bore about one mile to the south-westward of the former station, and there let go the best bower-anchor and cable, in twenty fathoms water, to ride until the swell of the sea should fall, when it might be practicable to grapple for the moorings, and find a better anchorage for the ship. As soon as the deck could be cleared the cable-end was hove up, which had parted at the distance of about fifty fathoms from the chain moorings. On

examining the cable, it was found to be considerably chafed, but where the separation took place it appeared to be worn through, or cut shortly off. How to account for this would be difficult, as the ground, though rough and gravelly, did not, after much sounding, appear to contain any irregular parts. It was therefore conjectured that the cable must have hooked some piece of wreck, as it did not appear from the state of the wind and tide that the vessel could have fouled her anchor when she veered round with the wind, which had shifted in the course of the night from N.E. to N.N.W. Be this as it may, it was a circumstance quite out of the power of man to prevent, as, until the ship drifted, it was found impossible to heave up the cable. But what ought to have been the feeling of thankfulness to that Providence which regulates and appoints the lot of man, *when it is considered* that if this accident

had happened during the storm, or in the night after the wind had shifted, the floating light must inevitably have gone ashore upon the Bell Rock. In short, it is hardly possible to conceive any case more awfully distressing than our situation would have been, or one more disastrous to the important undertaking in which we were engaged."

The dangers of landing a large band of workmen on a tide-covered rock are truly related in the following interesting narrative:—

"Soon after the artificers landed on the rock they commenced work; but the wind coming to blow hard, the 'Smeaton's' boat and crew, who had brought their complement of eight men to the rock, went off to examine her riding-ropes, and see that they were in proper order. The boat had no sooner reached the vessel than she went adrift, carrying the boat along with her; and both had even got to a considerable

distance before this situation of things was observed—every one being so intent upon his own particular duty that the boat had not been seen leaving the rock. As it blew hard, the crew, with much difficulty, set the mainsail upon the 'Smeaton,' with a view to work her up to the buoy, and again lay hold of the moorings. By the time that she was got round to make a tack towards the rock, she had drifted at least three miles to leeward; and having both the wind and tide against her, the writer perceived, with no little anxiety, that she could not possibly return to the rock till long after its being overflown. There were this morning in all thirty-two persons on the rock, with only two boats, whose complement, even in good weather, did not exceed twenty-four sitters; but to row to the floating-light with so much wind, and in so heavy a sea, a complement of eight men for each boat was as much as could with propriety be attempted

—so that in this way about one-half of our number was unprovided for. Under these circumstances, had the writer ventured to dispatch one of the boats, in expectation of either working the 'Smeaton' sooner up towards the rock, or in hopes of getting her boat brought to her assistance, this must have given an immediate alarm to the artificers, each of whom would have insisted upon taking to his own boat, and leaving the eight artificers belonging to the 'Smeaton' to their chance. Of course a scuffle might have ensued; and it is hard to say, in the ardour of men contending for life, where it might have ended. It has even been hinted to the writer that a party of the pickmen were determined to keep exclusively to their own boat against all hazards.

"The unfortunate circumstance of the 'Smeaton,' and her boat having drifted, was for a considerable time only known to *the writer* and to the landing-master, who

removed to the farther point of the rock, where he kept his eye steadily upon the progress of the vessel. While the artificers were at work, chiefly in sitting or kneeling postures, excavating the rock or boring with the jumpers, and while their numerous hammers and the sound of the smith's anvil continued, the situation of things did not appear so awful. In this state of suspense, with almost certain destruction at hand, the water began to rise upon those who were at work on the lower parts of the sites of the beacon and lighthouse. From the run of sea upon the rock, the forge-fire was also sooner extinguished this morning than usual; and the volumes of smoke having ceased, objects in every direction became visible from all parts of the rock. After having had about three hours' work, the men began pretty generally to make towards their respective boats for their *jackets and stockings*, when, to their

astonishment, instead of three they found only two boats—the third being adrift with the 'Smeaton.' Not a word was uttered by any one, but all appeared to be silently calculating their numbers, and looking to each other with evident marks of perplexity depicted in their countenances. The landing-master, conceiving that blame might be attached to him for allowing the boat to leave the rock, still kept at a distance. At this critical moment, the author was standing upon an elevated part of the rock, where he endeavoured to mark the progress of the 'Smeaton,' not a little surprised that some effort was not being made to bring the boat and attempt our relief. The workmen looked steadfastly upon the writer, and turned occasionally towards the vessel, still far to leeward. All this passed in the most perfect silence, and the melancholy solemnity of the group made an impression never to be effaced from his mind.

"The writer had all along been considering various schemes—providing the men could be kept under command—which might be put in practice for the general safety, in hopes that the 'Smeaton' might be able to pick up the boats to leeward when they were obliged to leave the rock. He was accordingly about to address the artificers on the perilous nature of their circumstances, and to propose that all hands should strip off their upper clothing when the higher parts of the rock were laid under water; that the seamen should remove every unnecessary weight and encumberance from the boats; that a specified number of men should go into each boat, and that the remainder should hang by the gunwales, while the boats were to be rowed gently towards the 'Smeaton,' as the course to the 'Pharos' or floating-light lay rather to windward of the rock. But when he attempted to speak, his mouth was so

parched that his tongue refused utterance, and he now learned by experience that the saliva is as necessary as the tongue itself for speech. He then turned to one of the pools on the rock and lapped a little water, which produced an immediate relief. But what was his happiness when, on rising from this unpleasant beverage, some one called out 'a boat! a boat!' and on looking around, at no great distance, a large boat was seen making towards the rock. This at once enlivened and rejoiced every heart. The timely visitor proved to be James Spink, the Bell Rock pilot, who had come express from Arbroath with letters. Spink had for some time seen the 'Smeaton,' and had even supposed, from the state of the weather, that all hands were on board of her, till he approached more nearly and observed people on the rock. Upon this fortunate change of circumstances sixteen of the artificers were sent at two trips in

one of the boats, with instructions for Spink to proceed with them to the floating-light. This being accomplished, the remaining sixteen followed in the two boats belonging to the service of the rock.

"Every one felt the most perfect happiness at leaving the Bell Rock this morning, though a very hard and even dangerous passage to the floating-light still awaited us, as the wind by this time had increased to a pretty hard gale, accompanied with a considerable swell of sea. The boats left the rock about nine, but did not reach the vessel till twelve o'clock noon, after a most disagreeable and fatiguing passage of three hours. Every one was as completely drenched in water as if he had been dragged astern of the boats."

After the second year's operations, however, the erection of a temporary barrack, which is represented in the cut upon next page, relieved the working party from these

dangerous voyages, but only to encounter further perils, of which the following description of the engineer gives a lively picture:—

FIG. 9.

"This scene—the sublime appearance of the waves—he greatly enjoyed while sitting at his window. Each wave approached the Beacon like a vast scroll unfolding, and in passing discharged a quantity of air, which

he not only distinctly felt, but was even sufficient to lift the leaves of a book which lay before him.

"The gale continues with unabated violence to-day, and the sprays rise to a still greater height, having been carried over the masonry of the building, or about ninety feet above the level of the sea. At four o'clock this morning it was breaking into the cook's berth (in the Beacon), when he rang the alarm-bell, and all hands turned out to attend to their personal safety. The floor of the smith's or mortar gallery was now completely burst up by the force of the sea, when the whole of the deals and the remaining articles upon the floor were swept away—such as the cast-iron mortar-tubs, the iron hearth of the forge; the smith's bellows, and even his anvil, were thrown down upon the rock. The boarding of the cook-house, or storey above the smith's gallery, was also partly carried

away, and the brick and plaster work of the fireplace shaken and loosened. It was observed during this gale that the beacon-house had a good deal of tremor, but none of that 'twisting motion' occasionally felt and complained of before the additional wooden sturts were set up for the security of the principal beams. Before the tide rose to its full height to-day, some of the artificers passed along the bridge into the lighthouse, to observe the effects of the sea upon it; and they reported that they had felt a slight tremulous motion in the building when great seas struck it in a certain direction about high-water mark. On this occasion the sprays were again observed to wet the balcony, and even to come over the parapet wall into the interior of the light-room. In this state of the weather, Captain Wilson and the crew of the 'Floating Light' were much alarmed *for the* safety of the artificers upon the

rock, especially when they observed with a telescope that the floor of the smith's gallery had been carried away, and that the triangular cast-iron sheer-crane was broken down. It was quite impossible, however, to do anything for their relief until the gale should take off. . . .

"The writer's cabin in the Beacon measured not more than four feet three inches on the floor; and though from the oblique direction of the beams of the beacon it widened towards the top, yet it did not admit of the full extension of his arms when he stood on the floor; while its length was little more than sufficient for suspending a cot-bed during the night, calculated for being triced up to the roof during the day, which left free room for the admission of occasional visitants. His folding-table was attached with hinges immediately under the small window of the apartment; and his *books*, barometer, thermometer,

portmanteau, and two or three camp-stools, formed the bulk of his movables. His diet being plain, the paraphernalia of the table were proportionately simple, though everything had the appearance of comfort, and even of neatness, the walls being covered with green cloth, formed into panels with red tape, and his bed festooned with curtains of yellow cotton stuff. If, on speculating on the abstract wants of man in such a state of exclusion, one were reduced to a single book, the Sacred Volume—whether considered for the striking diversity of its story, the morality of its doctrine, or the important truths of its Gospel—would have proved by far the greatest treasure."

The operations at the Bell Rock were commenced in 1807, and three long and irksome working seasons elapsed ere the building was brought above the high-water *level*; and it was not till February 1811,

that the light was first exhibited. The cost, including the establishment ashore at Arbroath, where the light-keepers live, was £61,000. The tower is 100 feet in height, 42 feet in diameter at the base, and 15 at the top, and contains six apartments, including the light-room. The light at the Bell Rock is revolving red and white, and was, even at the time of its first exhibition, fitted up with parabolic reflectors and argand lamps, according to the best catoptric principles of illumination; and the same kind of apparatus continues in use at the Bell Rock Lighthouse up to the present time—a strong proof of the degree of perfection to which Mr. Robert Stevenson had brought the catoptric system of illumination even at that early period.

Those who are curious to know what sort of a dwelling-place the Bell Rock Lighthouse affords in a storm, may get a faint notion from the frontispiece, which is

engraved from a spirited drawing by the late Mrs. Warden, the daughter of the engineer. The waves completely envelope the tower to the height of 60 or 70 feet, and, shooting up its curved outline, deluge the balcony and lightroom parapet with spray, which has been known to fall so heavily, even at that elevation, as to wash from its place the ladder used for cleaning the outside of the lightroom windows. The following is Mr. Stevenson's account of witnessing the effects of a heavy sea after the completion of the work :—

"He sailed from Arbroath with the tender, in a pretty hard gale from north-east, at four o'clock in the morning of the 9th of December, and at seven got close to the rock. The lighthouse now appeared in one of its most interesting aspects, standing calmly among the waves, while the sea around was in the wildest state of agitation. The lightkeepers did not seem

to be in motion; but the scene was by no means still, as the noise and dashing of the waves were unceasing. The seas rose in the most surprising manner to the height of the kitchen windows, or about 70 feet above the rock; and, after spending their force in a perpendicular direction, successively fell in great quantities round the base of the lighthouse, while considerable portions of the spray were seen adhering, as it were, to the building, and guttering down its sides in the state of froth as white as snow. Some of the great waves burst, and were expended upon the rock before they reached the building; while others met on the western side of the house, struck the base, and embracing the walls, where they dashed together and produced a most surprising quantity of foam. Though there was no possibility of effecting a landing to-day, yet the vessel lay "off and on" till low-water, when she bore away for the

Firth of Forth, leaving the inhabitants of the rock surrounded, and even enveloped, by the sea in its utmost fury, yet in a state of comparative safety, and enjoying feelings of the utmost security."

The Skerryvore Lighthouse, the last of these pillars founded on outlying reefs which we shall notice, has also been fully described by its engineer in his published narrative. It is exposed to the full "*fetch*" of the Atlantic Ocean; and its construction, on account of the foul ground by which it is surrounded, involved no small amount of risk and difficulty, although the aids of steam for towing the stone barges afforded a facility which was not enjoyed by the engineers of the Eddystone and the Bell Rock. The Skerryvore is further peculiar, inasmuch as it is not a solitary rock, but is surrounded by foul ground, which extends on either side of it for many miles. In the immediate neighbourhood of the principal

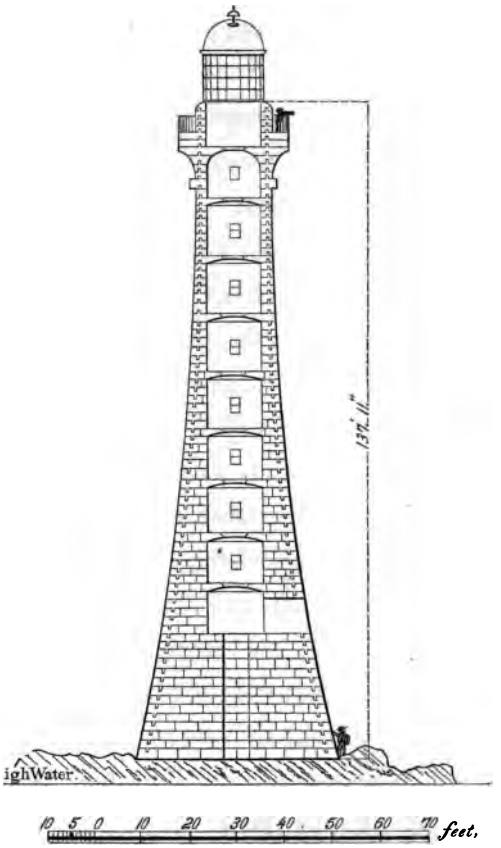


FIG. 7. THE SKERRYVORE LIGHTHOUSE.

on which the lighthouse is erected, no
:r than one hundred and thirty outlying

rocks were discovered, while others appear at intervals of some miles—the whole track of foul ground occupying a line of about seven miles. In a storm all these low-lying rocks are submerged, and cannot be distinctly seen, serving only to increase the tumult of the breaking waves in passing over them. Here, then, is a case different from either the Eddystone or the Bell Rock, demanding a powerful light placed on a high tower, and capable of being seen by vessels at a great distance, so as to warn them of their approach to the outlying dangers by which the lighthouse is surrounded. While, therefore, an elevation of 68 feet might suffice at the Eddystone, and the greater height of 100 feet—on account of the lowness of its foundation — was required at the Bell Rock, it is clear that a still higher tower was necessary at Skerryvore. Mr. Alan Stevenson accordingly resolved on adopting 140 feet as the

height; and both in its proportions and beauty of outline it greatly surpasses its rivals.

The proportions of the three towers are as follows:

| Lighthouse. | Height of Tower above first entire course. | Contents of Tower. | Diameter. | |
|---|---|---|---|---|
| | | | At Base. | At Top. |
| Eddystone . | 68 feet | 13,343 feet | 26 feet | 15 feet |
| Bell Rock . | 100 „ | 28,530 „ | 42 „ | 15 „ |
| Skerryvore | 138·5 „ | 58,580 „ | 42 „ | 16 „ |

In such a situation as that of Skerryvore everything had to be provided and transported from a distance. Barracks were erected at the workyard in the neighbouring Island of Tyree, and also in the Isle of Mull where the granite for the tower was quarried. A pier was built in Mull for the shipment and landing of materials; and at Tyree a harbour or basin was formed for the accommodation of the small vessel which attends the lighthouse. It

was besides found necessary, in order to expedite the transport of the building materials from Tyree and Mull to Skerryvore Rock, to build a steam-tug, which also served, in the early stages of the work, as a floating barrack for the workmen. In that branch of the service she ran many risks while she lay moored off the rock in a perilous anchorage, with two-thirds of the horizon of foul ground, and a rocky and deceitful bottom, on which the anchor often *tripped.*

The operations at Skerryvore were commenced in the summer of 1838, by placing on the rock a wooden barrack, similar to that employed at the Bell Rock. The framework was erected in the course of the season; but in a great gale which occurred on the night of the 3d November following, it was entirely destroyed, nothing remaining to point out its site but a few twisted iron stanchions, and attached to one of them the end of a broken timber, so

*shaken* and rent by dashing against the rock as literally to resemble a bunch of laths. Thus did one night obliterate all traces of a season's toil, and blast the hopes, which the workmen fondly cherished, of a stable dwelling on the rock, and of refuge from the miseries of sea-sickness, which the experience of the season had taught many of them to dread. A second and successful attempt was made to erect another house of the same description, strengthened by a few additional iron ties, and placed in a part of the rock which was hoped might possibly be less exposed to the breach of the heaviest waves than the site of the first barrack. This second house braved the storm. "Perched forty feet above the wave-beaten rock, in this singular abode," says Mr. Alan Stevenson, "with a goodly company of thirty men, I spent many a weary day and night—at those times when the sea prevented any one going down to

the rock—anxiously looking for supplies from the shore, and earnestly longing for a change of weather favourable for prosecuting the works. For miles round nothing could be seen but white foaming breakers, and nothing heard but howling winds and lashing waves. At such seasons much of our time was spent in bed; for there alone we had effectual shelter from the winds and the spray, which searched every cranny in the walls of the barrack. Our slumbers, too, were at times fearfully interrupted by the sudden pouring of the sea over the roof, the rocking of the house on its pillars, and the spurting of water through the seams of the doors and windows—symptoms which to one suddenly aroused from sound sleep recalled the appalling fate of the former barrack, which had been engulphed in the foam not twenty yards from our dwelling, and for a moment seemed to summon us to a similar fate."

The foundation-stone of the tower was laid on the 7th of July 1840, by the late Duke of Argyll, who, as proprietor of the adjacent Island of Tyree, took a great interest in the success of the works, and granted to the Commissioners of Northern Lighthouses free permission to quarry granite on any part of the Argyll estate—a freedom which was generously continued by the present Duke of Argyll. The light was exhibited for the first time in February 1844. It is a revolving light, and reaches its brightest state *once every minute.* It is produced by the revolution of eight great annular lenses around a central lamp with four wicks, and belongs to the first order of dioptric lights in the system of Fresnel. The light may be seen from a vessel's deck at a distance of eighteen miles. The entire cost of the lighthouse—including the purchase of the steam-vessel, and the building of the harbour at Hynish for the reception of the

small vessel (which now attends the light-house)—was £86,977 : 17 : 7.

"In such a situation as Skerryvore," says the engineer, "innumerable delays and disappointments were to be expected by those engaged in the work; and the entire loss of the fruit of the first season's labour in the course of a few hours was a good lesson in the school of patience, and of trust in something better than an arm of flesh. During our progress, also, cranes and other materials were swept away by the waves; our attending vessels were driven by sudden gales to seek shelter at a distance from the rocky shores of Mull and Tyree; and the workmen were left on the rock desponding and idle, and destitute of many of the comforts with which a more roomy and sheltered dwelling and the neighbourhood of friends are generally connected. Daily risks were run in landing on the rock in a heavy surf, in blasting the

splintery gneiss, or by the falling of heavy bodies from the tower on the narrow space below, to which so many persons were necessarily confined. Yet had we not any loss of either life or limb; and although our labours were prolonged from dawn to night, and our provisions were chiefly salt, the health of the people, with the exception of a few slight cases of dysentery, was generally good throughout the six successive summers of our sojourn on the rock. The close of the work was welcomed with thankfulness by all engaged in it; and our remarkable preservation was viewed, even by many of the most thoughtless, as in a peculiar manner the gracious work of Him by whom the very hairs of our heads are all numbered."

We close by noticing the floating-light used where no footing can be had whereon to found a tower; and though it fulfils its object less perfectly than a

lighthouse, yet, as admirably organised by the Trinity House of London, it is an indispensable part of our British Lighthouse system. The Lightship is a well-found vessel of one hundred and fifty tons burden, made fast to secure moorings. It costs, including all equipments, about £4000, and is maintained at a cost of about £1000 per annum. The lantern, which is five feet six inches diameter, surrounds the mast, on which it is raised when hoisted. The vessel is manned by a crew of eleven in number, so as to work the ship in case of her breaking adrift; and to their praise be it said—although there are forty-seven lightships on the coasts of England and Ireland—there is no instance on record in which the brave crews of these vessels have voluntarily run from their station in bad weather. Whether we consider, therefore, the important position which our lightships occupy among the

tortuous channels leading to our great ports of London and Liverpool, or the calm endurance of their ever-tempest-rocked inmates, they cannot fail to arrest our interest, and inspire us with thankfulness that men are found ever ready to discharge the most unenviable duties in the important and humane work of protecting the lives of our hardy seamen.

## Illumination of Lighthouses.

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What has been said will, we trust, satisfy our readers that, in spite of physical and engineering obstacles, lighthouses have been built on the pinnacles of sea-girt rocks, however high and precipitous, and on the rugged surfaces of shelving reefs however low and wave-swept; and we feel confident, that whenever a sunken reef can be shown to have led our goodly ships to destruction and their hardy crews to the grave, our lighthouse authorities will not shrink from the responsibility of founding a light-tower on it in spite of all difficulties. Having explained the construction of some of these important engineering works which serve as beacons and land-

marks by day, we have now to endeavour to show how they serve the far more important object of guiding the seaman by night.

In early times this problem was solved in a very off-hand manner. The light-towers of the last century, designed and executed in accordance with the highest engineering skill, however useful by day, were, after all, most imperfect guides to the benighted mariner. Indeed, the rude expedients adopted at that early period to give light to the sailor in a dark and moonless sky present a very curious contrast to the careful study which modern philosophers and engineers have bestowed on lighthouse illumination. If proof of this be wanted, we have only to refer to the twenty-four miserable candles, unaided by reflectors or any other optical contrivance, which shed their dim and uncertain light from Smeaton's famous Eddystone for nearly half a century after it was built.

But, indeed, all lights had not even the advantage of the glazed lantern which protected the candles of the Eddystone from the winter's blast and summer's breeze;—the grand Tour de Cordouan was originally lighted by blazing fagots of wood burned in an open chauffer, and many of the early lighthouses were open coal-fires. On the Isle of May, at the entrance to the Firth of Forth, a coal-light of this rude description was exhibited for the long period of 181 years; and, as it may be regarded as a model of the lighthouse of days now passed away, it may not be uninteresting to give a short account of it.

The Isle of May was originally a private light, the right of levying tolls on shipping being vested in the owner of the island. It was the only instance of the kind in Scotland, but there were many similar cases in England. The Commissioners *of* Northern Lighthouses believed it to

be advantageous that so important a light should be placed under public management, so as to secure for the shipping a better light, and exemption from the high passing tolls charged by the proprietor, and they entered into treaty with the Duke of Portland, the owner of the island, for the purchase of his rights. This negotiation resulted in the introduction of a bill into Parliament in 1814, authorising the purchase of the Isle of May, with the right of levying toll, for the sum of £60,000. So soon as the property came into the hands of the Commissioners they erected a new lighthouse, and on the 1st of September 1816, the old chauffer was discontinued, and a light from oil with reflectors was exhibited in its stead. We are enabled, from an old plan in our possession, to present the reader with a sketch (Fig. 8) of the original chauffer light of the Isle of May, with its pulley and box for raising the fuel to the top of the tower,

Fig. 8.

and its inscription-stone above the door bearing the date of 1636. The consumption of coal in this open chauffer was latterly about 400 tons per annum. It was one of the best coal-fires in the kingdom, and three men were employed to keep the bonfire burning, so that its inefficiency as a light was not due to any want of outlay in its

support. But its appearance was ever varying: now shooting up in high flames, again enveloped in dense smoke, and never well seen when most required. When Mr. R. Stevenson visited the island, with a view to its purchase by the Commissioners, he was told by the keeper that in violent gales the fire only kindled on the *leeward* side, and that he was in the habit of putting his hand through the *windward* bars of the chauffer to steady himself while he supplied the fire with coals, so that in the direction in which it was most wanted hardly any light was visible! Nothing can be worse than any variableness or uncertainty in the appearance of a light. Better far not to exhibit it at all, than to show it irregularly; and the coal-lights were so changeable and destitute of characteristic appearance as to be positively dangerous. This indeed was too sadly proved by the loss of H.M. ships "Nymphen" and "Pallas," which, on the

19th December 1810, were wrecked near Dunbar, the light of a lime-kiln on the coast of Haddington having been mistaken for the coal light of the Isle of May. Fortunately only nine of their combined crews of 600 men perished; but the vessels, valued at not less than £100,000, became total wrecks.

But these early lights, which were variable in power and visibility, and destitute of a proper characteristic appearance, had other disadvantages, for unfortunately they sent the same amount of light up to the sky and down upon the ground as they shed upon the sea; and inasmuch as it is from the sea only that a lighthouse requires to be viewed, it is obvious that most of the light from these great bonfires was utterly lost to the mariner, for whose use their flames were nightly fed by tons of coal or piles of timber. Now the idea of collecting these stray rays from their useless illumination of the

sky and of the ground, and, as shown in Fig. 9, throwing them into a direction that would give more light to the sailor, formed

FIG. 9.

the commencement, and is the object of lighthouse optical engineering. What we mean may perhaps be made more clear by the aid of a diagram. A lighted candle

FIG. 10.

FIG. 11.

(Fig. 10) sends forth its naturally diverging rays, as shown by dotted lines, in all directions, lighting up the whole roof, floor, and

walls of the chamber in which it stands; but on placing behind it a reflector, *a b*, (Fig. 11), we are enabled, by adjusting the flame to the focus, to collect all the rays that fall upon the surface of the reflector, and to throw them forward, as shown by the parallel lines, so that the light which formerly passed backwards and was expended in illuminating the chamber is thrown in the opposite direction, and forms a beam of light of great intensity, because of the greater number of rays transmitted; and therefore, if shown towards the sea, it will be more useful to the mariner than the naturally diverging rays from the unassisted flame of the candle. This was the first step in what is called the catoptric* or *reflecting* system of illumination. Again, instead of placing a reflector *behind* a light, the same object may be obtained by placing a lens, *a b*, *in front* of it, as shown in Fig. 12. In this case

* From the Greek κάτοπτρον, a mirror.

the lens has the effect of *refracting*, or bending all the rays impinging on it into the direction shown by the hard lines. The

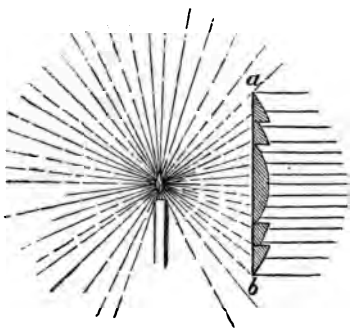


FIG. 12.

stray rays are thus collected and sent forward in a beam of greater intensity; and this was the first step in what is called the dioptric* or *refracting* system.

It would be altogether out of place to give a history and exposition of the catoptric and dioptric systems of lighthouse illumination. All that we aim at is to give our non-professional readers, in as simple phraseology as we can, a plain description

* From διὰ, through, and ὄπτομαι, I see.

of some of the apparatus most generally employed for the illumination of lighthouses; and if we succeed in doing this, we shall have attained our object.

The early reflectors used in lighthouse illumination, as described by Mr. W. Hutchinson of Liverpool, in a volume on "Practical Seamanship," published in 1791, consisted of small pieces or facets of common mirror-glass arranged in a hollow mould and fixed in their places by plaster-of-paris; but soon afterwards the facets of mirror-glass, though forming good instruments for their day and of their kind, were discarded, and the reflectors were made of copper plated with silver and brightly polished. The reflectors are carefully formed to the parabolic curve, and that curve was selected because all the rays, falling on the surface of a parabola from a luminous point placed exactly in its *focus*, are projected in directions parallel to its

axis, so that when the axis of the reflector is pointed towards the horizon a strong cylindric beam of light is thrown forward in that direction. The reflector is illuminated by an argand burner, and its power as used for revolving lights has been estimated at about 450 times that of the unassisted flame. Were the light which is placed in the focus sufficiently small, and the form of the instrument *perfect*, the beam of light projected would be no larger than the diameter of the reflector, the largest of which is twenty-five inches, so that the space illuminated at the horizon would be a small disc of only that size, and the instrument would thus be useless for lighthouse illumination, as the small pencil of light which it projected might never chance to come within the mariner's vision. But as the argand lamp-flame, instead of being a mathematical point, is of considerable size, the rays passing from the outer or *ex-focal*

portion of the flame are not sent parallel, but have a certain amount of divergence which, with a flame an inch in diameter placed in a reflector of four inches of focal distance, is equal to 14° 22′. This divergence or spreading of the rays causes the light to be visible over a considerable extent of the horizon, and enables us to arrange these instruments on a circular frame in such a way that the rays from the different reflectors, instead of shining in so many distinct beams, blend together and form by their union a continuous band of light of nearly uniform intensity all round the horizon, so that what has been termed the imperfection of the instrument is in reality that property which renders it practically useful. Such an arrangement forms what is called the *fixed* catoptric light; and if it be desired to produce a *revolving* light, all we have to do is to place one or more reflectors on a frame having four

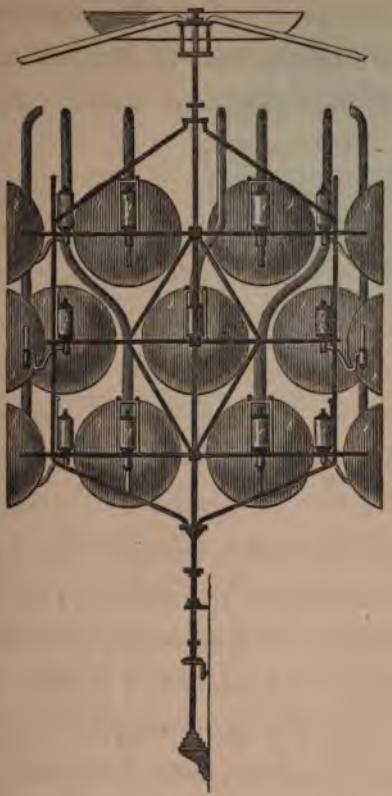

FIG. 13.

les, as shown in Fig. 13, and by causing is frame to revolve by clockwork, we shall ve alternately the sides and the angles of

the frame presented to the observer, who will see a bright flash of light as each side bearing the reflectors comes into view,

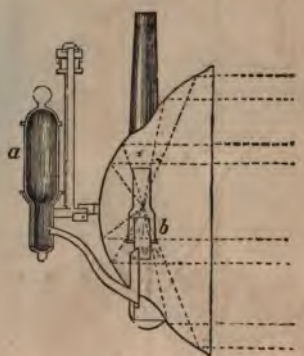


FIG. 14.

succeeded by dark intervals. Fig. 14 represents a section of the reflectors as used in the Northern Lighthouses, with the improvements introduced by Mr. Robert Stevenson; *a* is the fountain for the oil; *b*, the burner; and the reflected rays are shown by dotted lines. In Fig. 15, in which the reflector is not shown in section, the lamp is represented as lowered down from the reflector by means of a sliding apparatus

for guiding it. The object of this arrangement is to allow the lamp to be removed while the reflector is being polished, and to

Fig. 15.

insure its being returned to its exact position in the true focus.

The dioptric system of illumination originated with the late eminent Augustine Fresnel. Instead of the independent burners used in the foci of reflectors, he conceived the idea of using one large central flame $3\frac{1}{2}$ inches in diameter and 4 inches in

height, and arranging round it 8 large plano-convex lenses measuring 3 feet 3 inches in height and 2 feet 6 inches in breadth, so as to refract the light from the great central lamp in the manner explained in Fig. 12. These lenses, being fixed on a frame and made to revolve, produce the same effect as reflectors arranged in the manner we have described; for, as each face bearing a lens comes round to the eye of the observer, he sees a bright flash, which is succeeded by a period of eclipse or darkness. The lenses employed by Fresnel were on the construction suggested by Buffon, and improved by Condorcet, for burning-glasses in the year 1788. The advantages of that construction will be readily understood. If a lens of 3 feet 3 inches diameter were ground to a continuously spherical figure, it is obvious that it would attain a great thickness at the axis, and that the loss of light by absorption

in its passage through the thick glass, as well as by what is called spherical aberration, would be very considerable. But the lens used in lighthouses is formed so as to avoid these disadvantages. Fig. 16 is an

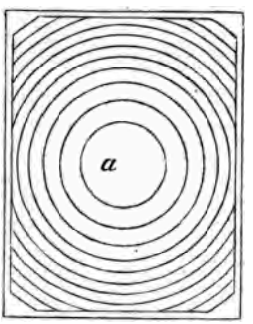


FIG. 16.

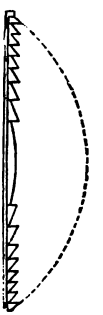

FIG. 17.

elevation and Fig. 17 a section of this instrument, which is called the *polyzonal** or *annular*† lens, because it consists of a central lens (*a*) surrounded by a series of separate *zones* or rings of glass held together with cement. This beautiful arrangement, it will be seen, admits of the thickness of

* From the Greek πολὺς, many, and ζώνη, a belt or zone. † Annulus—a ring.

glass being greatly reduced, because were the surface of the lens ground to a continuous curve, it would assume a form approximating to that represented by the dotted line. It also allows the surfaces of the zones, according as they recede from the axis of the lens, to be ground to the necessary curvature for correcting the spherical aberration. Fresnel's lenses were made of crown-glass, and their illuminating effect when lighted by the large four-wick lamp has been estimated at about 3000 argand flames, or about seven reflectors. Their divergence is less than that of the reflector, being only about 5° 9′. Fresnel limited the height of his lenses to 3 feet 3 inches, which subtends an angle of about 56° at the focus. Beyond that limit the lenticular action could not be advantageously pushed, owing to the obliquity of the incident rays on the surface of the lens; and in order to intercept that portion of the

light from the great lamp which passed above the lenses, Fresnel used a combination of refractors and reflectors; but as that part of Fresnel's revolving-light apparatus is now superseded by Mr. Thomas Stevenson's totally reflecting holophotal* prisms, we need not here explain its construction. Suffice it to say, that the holophotal prisms effect by means of one agent what formerly was done by two, and moreover they do this by what is called *total* or *internal* reflection within the glass, instead of reflection from metallic mirrors, which absorb one half of the whole rays incident on their surface, so that a great saving of light is effected. Total or internal reflection was only applied by Fresnel to the *fixed* portion of lighthouse apparatus. We feel, however, that we owe an apology to some of our readers for using terms of which we do not give the precise meaning,

* From ὅλος, entire, and φῶς, light.

but the popular nature of this article prevents us from explaining such terms as "spherical aberration" or "total reflection." This could not be done without using dry diagrams and hard words, which we fear would not be pronounced to be "Good;" and therefore we must ask the reader to be contented with the explanation afforded by the engraving accompanying this notice (Fig. 18), which represents the interior of a lightroom with a first-class holophotal revolving apparatus. The central parts of the glass-work are the polyzonal lenses, and the upper and lower tiers are the panels of holophotal prisms. The case containing the machinery for driving the apparatus occupies the lower portion of the lightroom, and against the wall are the clock, signal pipes, and barometer. If further information be desired, we must refer the reader to the published treatises on the subject of Lighthouse Illumination.

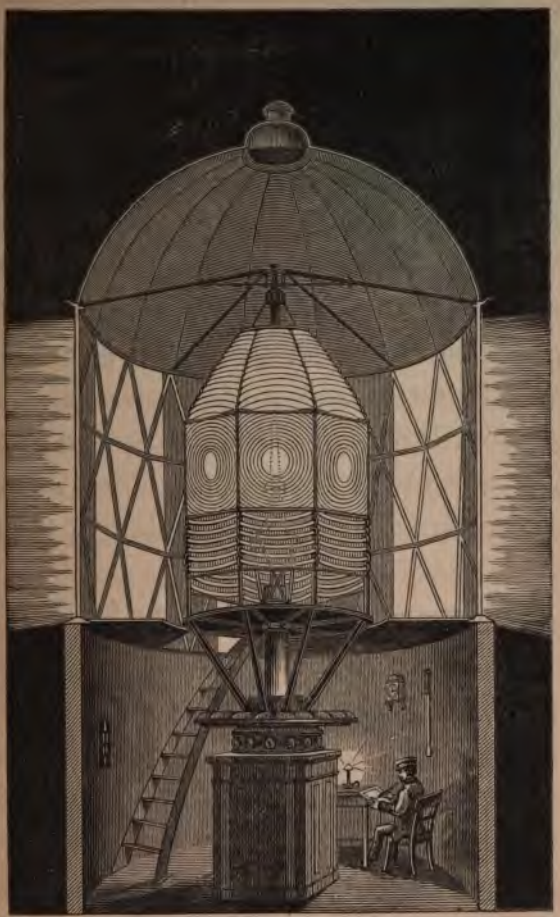

FIG. 18.

But the large polyzonal lens is properly suited only to revolving lights; it was not until Fresnel extended his researches to the improvement of fixed lights that he completed his dioptric system of light-house illumination. He conceived the possibility of forming a hoop of glass, having the same profile as a vertical section through the axis of a polyzonal lens. The action of such an instrument allows the rays from a lamp in its centre to spread freely in the horizontal plane, while it only refracts them vertically, and thus produces a powerful band of light of equal intensity all round the horizon. But much of the light would obviously pass above and below this hoop, and in order to intercept all such stray light, Fresnel designed for his fixed light a series of totally reflecting prisms to be ranged above and below, so formed as to intercept all the rays falling upon them, and *to project* them in a direction parallel

to those issuing from the central belt. Fresnel did not, however, from the difficulty of its construction on a large scale, apply this beautiful apparatus in its most perfect form to large or first-order lights, but restricted it to small harbour lights. Instead of a hoop he used for large lights a polygon of narrow lenses, with a sufficient number of sides to enable the lenses, in consequence of their divergence, to give at the angle formed by the junction of two of them a light not materially inferior to what is produced by one of the sides; and instead of upper and lower prisms, he employed inclined metallic mirrors.

When Mr. Alan Stevenson was instructed by the Commissioners of Northern Lighthouses to convert the fixed catoptric light of the Isle of May into a dioptric light, he resolved to attempt the construction of a truly cylindric hoop for first-class lights, instead *of a polygon*; and after overcoming

various difficulties the work was successfully accomplished by Messrs. Cookson of Newcastle, and employed for the first time at the Isle of May. He further proposed to make the sections of the great central hoop, which are called "cylindric refractors," rhomboidal, so that the junction of the frames inclosing the glass-work being inclined from the perpendicular should not in any azimuth intercept the light throughout the whole height of the refracting belt; and lastly, he suggested the adoption (on a larger scale) of Fresnel's totally reflecting prisms as a substitute for the inclined mirrors in the first-class lights; and in carrying out this latter suggestion, he has acknowledged the obligations he was under to M. Leonor Fresnel, the brother of the distinguished inventor of the dioptric system, for his kind assistance and co-operation.

All that was then required to perfect this beautiful apparatus was the introduction

inclined or diagonal framing, and a
tern with diagonal astragals (as shown

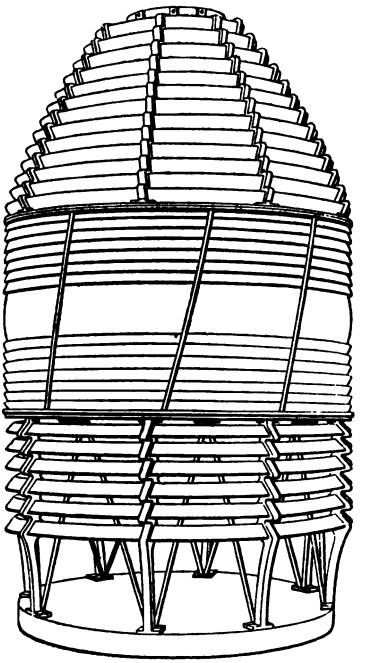

FIG. 19.

the engraving of the interior of the light-
ım), so as to avoid the interception of
ıt caused by the interposition of an

upright bar between the flame and the eye of the observer. Fig. 19 represents the first-class fixed light apparatus in its most improved form; and the reader can easily imagine that the rays proceeding from a lamp placed in the centre of this cage of glass, which is 6 feet in diameter and 10 feet in height, are so refracted by the middle belt and reflected by the upper and lower prisms as to be gathered into one band of light of uniform intensity, which is spread over the surface of the sea, where alone it can be seen by the mariner.

The manufacture of dioptric apparatus was long confined to the French, who greatly excelled us in the purity of the glass and the perfection of the machinery for grinding and polishing the surfaces; but Messrs. Chance of Birmingham have devoted a compartment of their extensive works to the manufacture of glass for lighthouse purposes, and, having adopted

every conceivable mechanical arrangement for grinding and polishing prisms of any required form, they can now turn out the most complicated apparatus finished in a very high style of workmanship. The manufacture of lanterns, and of the whole framing and machinery necessary for a lighthouse, has been brought to a very high degree of perfection by Mr. Milne of Edinburgh.

Such is a very brief outline of the catoptric and dioptric systems of illumination; and to illustrate the different applications of optical engineering we may describe very shortly some arrangements of Mr. T. Stevenson to meet the requirements of particular localities. One of these is what is called the *condensing light.* In fixed lights of the ordinary construction the rays are distributed, as we have just explained, all round the horizon; and such an apparatus, though well adapted for an

island or rock surrounded by the ocean, is quite inapplicable in a narrow sound or arm of the sea as shown in Fig. 20.

FIG. 20.

On the side next the shore, marked Isle of Skye, no light is required; across the sound a comparatively feeble beam is all that is needed; while along the sound in the direction of A, B, and C, D, where the distances are greater, the light requires to be more powerful. If an ordinary fixed light were employed in such a situation, and made of sufficient power to light the channel in the directions A, B, and C, D, it is obvious that it would be much

too strong for the shorter distance across the sound, while the light shining towards the land would be altogether thrown away. Such an arrangement would therefore occasion a great expenditure of oil for no purpose. By using the condensing apparatus the whole of the light proceeding from the flame is allocated or distributed in different directions in exact proportion to the distances to which it is wanted to extend, and the stray light, which would otherwise be wasted upon the land, is thrown or *condensed* in the directions in which the strongest light is required. This effect is produced by combining certain straight prisms and other optical agents with the ordinary lighting apparatus, and was first used in 1857 at three lights in the Sounds of Skye and Mull on the west of Scotland. A small burner was found to produce, in the only direction in which great power was required, a light equal to the largest class

of apparatus; and the saving in oil, etc., on the three lights referred to, was estimated at from £400 to £500 per annum.

Another application of straight prisms, called the "apparent light," has been found very useful in indicating the positions of tide-covered rocks lying near the shore. In this case the apparatus is placed on the top of a beacon erected on the rock, and is illuminated by a beam of parallel rays thrown from an apparatus *on the land*. The effect produced may be compared to that of a ship's lantern placed on the top of the beacon, and it has been called *apparent* because the light appears to proceed from the beacon, whereas the light itself is on the neighbouring shore, and its reflection *alone* is visible. This apparatus has been for many years in use at Stornoway, where it has been found by seamen seeking shelter during the night to be quite successful.

The question of *distinction* still remains to be noticed. It is obvious that, if all lights had the same appearance, they might quite as well not be exhibited, as they would not enable the mariner to discover his position on the coast, and would thus lead to utter confusion; each light, whether catoptric or dioptric, must therefore have its own distinctive appearance, so that the sailor can readily distinguish and instantly recognise it. The following are the distinctions most generally adopted, care being taken to arrange the order of the lights so that those having the same character may be as widely apart as possible.. The *fixed white* exhibits, as its name implies, an uniform and steady appearance; and we obtain a *fixed red* by using lamp-glasses stained of a ruby colour. The *revolving white* is produced by the revolution of reflectors or lenses in the manner already described; and as the revolution exhibits a light

gradually increasing to full strength, and in the same gradual manner decreasing to total darkness, its appearance is extremely well marked,—so well, indeed, that when Inchkeith was changed from a fixed to a revolving light, a certain old lady, who had beguiled many a sleepless hour in watching it, was greatly puzzled by its successive appearance and eclipse, and declared in the morning that the poor light-keeper was much to be pitied, for "no sooner was his lamp lighted than it went out, and if it had been lighted once, it had been lighted a hundred times!"

The succession of *red and white* lights is caused by the revolution of a frame, whose alternate faces carry reflectors with chimneys of clear and ruby-coloured glass. And here we may mention that various colours have been tried, such, for example, as green and blue; but these colours are visible at distances so short as to render

them unfit for great sea-lights, the red alone being suitable as a marked distinction visible at great distances. The *flashing* light is produced in the same manner as the revolving light; but owing to a somewhat different arrangement of apparatus, and a faster motion of the revolving frame, a totally different and very striking effect is produced. The brightest and darkest periods being but momentary, this light is characterised by a rapid succession of bright flashes, from which it gets its name. The *intermittent* light is distinguished by bursting suddenly into view and continuing steady for a short time, after which it is eclipsed for half a minute by shades worked by machinery. The last two distinctions were invented and introduced into the northern lighthouses by Mr. Robert Stevenson. *Double* lights are sometimes exhibited from the same tower, one above the other, and sometimes from different

towers, in which latter case, when kept in one line, they are generally designed either to indicate some navigable channel or to guide vessels past some danger.

Some lights which are near towns have been illuminated with gas, but its application cannot be extended to remote localities, and colza oil, obtained from the seed of a species of wild cabbage, is used in most of the lights in Britain. The argand lamp, with a standard flame one inch in diameter and two inches in height, consumes about 40 gallons; and the first-class lamps for dioptric lights, with a standard flame of $3\frac{1}{2}$ inches in diameter and four inches in height, burn about 800 gallons per annum. These large lamps have four concentric wicks, the outer or largest being $3\frac{1}{2}$ inches in diameter. The oil for their supply is forced up in a constant stream by small pumps worked by machinery. The supply is much greater than the consumption, and the overflow of

oil through the wicks, which falls back into the cistern, prevents the soldering of the metal wick-holders from being melted by the great heat generated, and if the overflow ceases, the burner is at once destroyed. A small bell struck by the same machinery that pumps the oil indicates that the machine is continuing to do its duty; so soon as its constant *tingle* ceases, it is time for the light-keeper to start to his feet and look out for the safety of his lamp. The distance at which a light is visible depends on its elevation above the sea, and varies of course with the state of the atmosphere. We are not aware of any oil light having been seen at a greater distance than the holophotal light of Allepey, in Travancore, which is visible from the Ghaut Mountain, distant about 54 statute miles. Still in our ever-changing climate, subject as it is to cloud and haze, there can be no doubt that any method of increasing the intensity of

our lights should be hailed with pleasure both by the engineer and the sailor. We cannot get more light with our present apparatus, for if we increase the size of the flame we lose by unnecessary divergence. What we want, therefore, is light of greater intensity; and it is that important quality which gives to the lime-ball light, and to Professor Faraday's electric light, all their value for the purposes of illumination. The oxyhydrogen or lime-ball light has not as yet been found to work steadily or satisfactorily. The magneto-electric light has been adapted to lighthouse illumination by Professor Holmes, and was tried by the Trinity House of London at the South Foreland in 1858, and latterly at Dungeness in 1862. A steam-engine forms a part of the apparatus required for producing the electric light, which would doubtless prove a barrier to its use in our rock stations such as the Eddystone or Bell Rock; but the chief

difficulty which has been experienced in bringing this light into practical use is its tendency to sudden extinction. The Elder Brethren of the Trinity House reported in September 1862, "that with their present knowledge of the electric light they do not feel justified in sanctioning its exhibition from any lighthouse where provision is not made for its instant substitution by a light in ordinary use, it appearing to them that the contingencies to accident attaching to the electric light render such precaution absolutely necessary." The same perseverance and skill that have brought the electric light to its present state may, however, perfect it as a practical source of illumination; and to ensure that desirable end it cannot be in safer hands than the Trinity House of London, aided by the advice of Professor Faraday and Professor Holmes.

But, however intense the light may be, it is confessedly wholly unavailable to the

mariner in certain states of the atmosphere. We have, by repeated observation and measurement, ascertained that it is no uncommon thing during fogs for objects in daylight to become invisible at the distance of from 200 to 210 feet; and at night for street-lamps to be obscured at distances of from 280 to 300 feet. On one occasion, indeed, we found that in daylight objects on a country road ceased to be visible at 60 feet. In such cases, when the sun in the firmament is obscured, even the electric light would fail to reach the mariner's eye, and we believe that slow sailing and a free use of the sounding lead are the sailor's best resources under such circumstances. During the erection of the Bell Rock Lighthouse, the landing boats had to make passages between the attending vessels and the Rock, and much inconvenience and danger occurred during foggy weather, as they sometimes missed the vessels al-

together, and were tossed about for a whole night. And when it is considered that the aggregate time of low-water work, during the first two seasons, did not amount to forty-two days, it will at once be seen how important it was to miss no opportunity of effecting a landing during spring tides. All devices were therefore tried in the shape of fog signals, for, during that state of the atmosphere, the sea is sometimes very calm; and Mr. Stevenson has stated as the results of these trials, that sound is much lost in foggy weather and is heard at a comparatively short distance, and that the "tremulous" and sustained noise produced by a horn or bugle is preferable to a bell or even a gun. The shrill shriek of the steam or railway whistle, being now used in all steamers, is so common a sound at sea, as to render it not suitable as a lighthouse fog-signal; but at some of our lighthouses and harbours, large bells and

gongs are tolled, and at others guns are discharged; and Mr. Daboll, an American, has introduced a trumpet sounded by a blast of air compressed by an engine or other power, which is said to produce a wonderful effect: and we are glad to learn that it is about to be tried in this country by the Trinity House. The great drawback to all such signals is the difficulty during a fog of telling from what direction the sound proceeds, and of this we have known repeated instances. Sound may indicate the *nearness* of a danger, but it does not tell in what *direction* it lies. The subject, however, is highly important, and we hope that the papers of Dr. Gladstone, read before the Royal Institution, and of Mr. Cuningham, the secretary to the Commissioners of Northern Lighthouses, read before the Royal Scottish Society of Arts, may have the effect of directing further attention to it.

## MANAGEMENT OF LIGHTHOUSES.

—o—

THE management of our lights is entrusted to three Public Boards, viz., the Trinity House, for England and the Channel Isles; the Commissioners of Northern Lighthouses, for Scotland and the Isle of Man; and the Ballast Board of Dublin, for Ireland. The Merchant Shipping Act provides, that in the erection of new lights the Commissioners of Northern Lighthouses and the Ballast Board are, to some extent, under the control of the Trinity House, and that the whole of the three Boards, in so far as regards proposals for new lights and matters of expenditure and accounting, are subject to the control of the Board of Trade. Whatever diversity of opinion

may exist as to the provisions of this Act, there can be no doubt that the enactment, which provides that in future the expenditure for new lighthouses should be defrayed out of the Consolidated Fund, has been of great benefit to the shipping interest. Previous to this the only funds applicable to the execution of new works were the surplus dues which remained unexpended after the ordinary maintenance of the lighthouses had been provided for; and while this necessarily imposed an extra burden on the shipping who paid the dues, it also delayed the erection of lighthouses in localities where they were much needed, and where they were only postponed from want of money. But when the cost of new works came to be defrayed out of the Consolidated Fund, the same restriction no longer existed; and on the shores of Scotland alone no fewer than eighteen new lighthouses and fourteen new beacons have

been erected, at a cost of about £175,000, since the passing of the Merchant Shipping Act, while the dues now levied, being only what are required for the ordinary maintenance of the lights, have been greatly reduced. The number of lights in the United Kingdom under the management of the three public boards and local authorities is now about 357, the light-ships 47, the beacons 261, and the buoys 1109.

Two light-keepers have the charge of each of the ordinary lighthouses, and at the Eddystone there were originally the same number; but one of the Eddystone light-keepers, having been taken suddenly ill, died, and his only survivor feared to commit the body to the sea lest he should be charged with murder in absence of all evidence of the man having died a natural death. He accordingly allowed his dead comrade to remain so long in the lighthouse that it became uninhabitable; and he was

driven in despair to remain in the balcony till the attending boat could land at the rock to relieve him. To guard against the recurrence of so unhappy a casualty all such inaccessible stations are now provided with four keepers, three of whom are constantly on the rock, while the fourth has his turn ashore with his family, and it is his duty to watch a daily signal made by hoisting a ball in token that all is well. If the ball be not raised, it is his duty to proceed to the lighthouse in the attending boat with all convenient speed. But at such places as the Bell Rock it is sometimes impossible to land for weeks together, and previous to the employment of steam a period of nearly three months has been known to elapse before the change of light-keepers could be effected. The process of landing amid surf and breakers on tide-covered reefs or rock-bound coasts, and again boarding the tender in a heavy sea-

way, is not the most agreeable duty connected with the service; and it is not with feelings of pleasure that we look back on some of our "difficult landings" on the northern shores of Shetland, the western coast of the Hebrides, or the Pentland Firth.

It may interest some of our readers to know that originally carrier-pigeons were used at the Bell Rock as a means of communication. A letter being tied to the leg of the feathered messenger, he was liberated from his prison, and soaring high into the air, he flew direct with his tidings of weal or woe to the signal tower at Arbroath, a distance of 11 miles, which he traversed in as many minutes, thus outstripping the speed of our express trains on our fastest railways; but this plan was more curious as a fact in natural history than convenient as a mode of communication, and was after some time discontinued.

From what has been said as to the im-

portance of strict regularity in the exhibition of lights, we think our readers will fully appreciate the vast importance of securing trustworthy and capable men to perform the highly responsible duties of light-keepers, and from pretty long experience we are enabled to state that the greater number of men so employed in the northern lighthouses have been of a superior class, fully alive to the importance of their duties, and some of them occupying much of their leisure time in the improvement of their mind. The regulations imposed on light-keepers are very stringent, but not more so than the responsible nature of the duties demands, and, coupled with periodic inspections by members of the Board and their officers, to see that these regulations are faithfully observed, a discipline somewhat akin to that of the military or the naval service is maintained. As an illustration of this, we *may* mention the signal tubes which com-

municate from the lightroom to the bedrooms of the dwelling-houses, and no man, on *pain of dismissal from the service*, is permitted to leave the lightroom on any pretence whatever without in the first place summoning his colleague to supply his place. A constant watch is thus kept up so long as the lamps are burning; and in a long Shetland winter night, extending from three in the afternoon till nine in the morning, the four hours' watches, which are taken by rotation, come to be a pretty heavy part of the duty. Seated in the isolated lightroom, far from the bustle and din of town life, the lightkeeper spends many an hour of absolute seclusion, but, strange as it may seem, even he is not altogether exempt from the annoyance of nocturnal visitors. Whole flocks of small birds, driven by the wind from the coast and attracted by the dazzling light, have sometimes, like a living shower, been driven against the lantern and de-

stroyed; and even large sea-birds, hurried onward by the gale, have occasionally struck the thick plate-glass, and shivering it to pieces, fallen dead on the lightroom floor, while the lamps have been wholly or partially extinguished. The keeper then sounds his alarm, and applying a storm pane (which is always in readiness in case of accident) to the breach made by the misguided gull, his lamps are speedily re-lighted. It is not often, however, that the midnight reveries of the light-keeper are so interrupted, and night after night, amid the roar of waves and the howl of tempest, he holds his watch in solitude. A circulating library (in the truest sense of the word) has in some cases been sent round the coast from station to station, each box containing a stock of well-selected books, which after a reasonable sojourn are packed up and forwarded to the next lighthouse.

*It* must not, however, be supposed that

the light-keeper's time is not fully occupied. In summer, where the soil admits of it, he has a garden to till, and in winter, when the night-watches are protracted, the ordinary duties of the lightroom, if faithfully discharged, occupy a large portion of the short day. A careful statement must be made of the oil and other stores nightly expended; a record must be kept of the barometer, thermometer, raingauge, and direction of the wind; and a journal given of the number of vessels seen to pass the lighthouse, and anything that may happen worthy of notice at the station.

Proposals have been made to extend telegraphic wires to some of the outlying lighthouses, so that outward and inward bound vessels might signal on passing the lighthouse, and the keepers might telegraph these messages for the benefit of their owners or insurers. But in reply to this suggestion we have always maintained that

the light-keeper's first duty is to secure the efficient and regular exhibition of the light under his charge, and that no encouragement should be given to impose upon him any occupation that might interfere with his legitimate duty, more especially if the extent of such occupation could not be defined, and the time of its execution from day to day restricted to certain hours. It has also been suggested that lighthouses might be made available as lifeboat stations; but the same difficulty applies with even greater force to such a proposition, because, if the light-keepers were, in case of shipwreck, to render any personal service at all, it would necessarily take them away from the lighthouse in states of the weather when it is all-important that the lightroom duties should be performed with, if possible, more than ordinary assiduity, when the outside of the lantern windows has perhaps to be cleared several times in the course of

the night of snow-drift, and the inside of condensed water caused by extreme cold. But, indeed, as lifeboats can only be used in the neighbourhood of towns or villages where the population affords a sufficient number of horses and men to launch them, and a sufficient crew of willing and experienced seamen to man them, we have never been able to see how our lighthouse stations can in any way be made available for such a purpose.

To the remote and isolated sites of many of our northern lighthouses, the easiest, and, in many cases, the only communication is by sea, and the various stores required for maintaining them are conveyed to the Northern Lighthouse Stations by the Commissioners' steam-tender "Pharos," an arrangement which is to some extent adopted in England and Ireland; but the geographical formation of the country renders the English and Irish lights less dependent on water-communication than

those of Scotland, with her far-stretching highlands and numerous outlying islands. In many parts of Scotland, indeed, the light-keepers have no opportunity of attending church, or their families a school; and this evil is, as far as practicable, lessened by making periodical changes in the appointments to these remote stations. The Commissioners of Northern Lighthouses are consequently in many cases obliged to make provision for medical attendance, and they have, with laudable consideration for the interests of their servants, a missionary as one of their regular officers, whose duty it is to pay visits to certain remote stations, remaining from one to four weeks, according to the necessities of the case and the number of young people to receive his instructions. There are fifteen of the Northern Lighthouse Stations regularly visited by Mr. Easton, *the* missionary to the Board; and the

isolated character of these places, and the necessity which exists for providing for the spiritual wants of their secluded inhabitants, are borne out by the following tabular statement of stations visited by the missionary, from which it will be seen that in some cases they are upwards of twenty miles removed from church or school.

| Number of Lighthouse. | Distance from Medical Aid, in Miles. | Distance from Church and School in Miles. | Nature of Communication. |
|---|---|---|---|
| 1 | 5 | 5 | 4 miles by water, 1 mile by road. |
| 2 | 9 | 9 | Road. |
| 3 | 9 | 2 | Water. |
| 4 | 10 | 5 | 6 water, 4 road. |
| 5 | 18 | 18 | Water. |
| 6 | 15 | 8 | 11 water, 4 road. |
| 7 | 22 | 9 | 13 water, 9 road. |
| 8 | 23 | 23 | 16 water, 7 road. |
| 9 | 12 | 5 | 4 water, 8 land. |
| 10 | 24 | 20 | Water. |
| 11 | 34 | 14 | Road. |
| 12 | 14 | 8 | Road. |
| 13 | 6 | 6 | Water. |
| 14 | 6 | 6 | Water. |
| 15 | 10 | 10 | Road. |

At most of these stations, therefore, the families are almost wholly excluded from the privilege of attending church, and on one occasion a light-keeper took his child a journey of thirty-five miles to be baptised! The missionary now baptises most of the children, but he has never dispensed the sacrament of the Lord's Supper, and if he were enabled to do so it is believed it would greatly enhance the value of his ministrations among his widely scattered and secluded flock.

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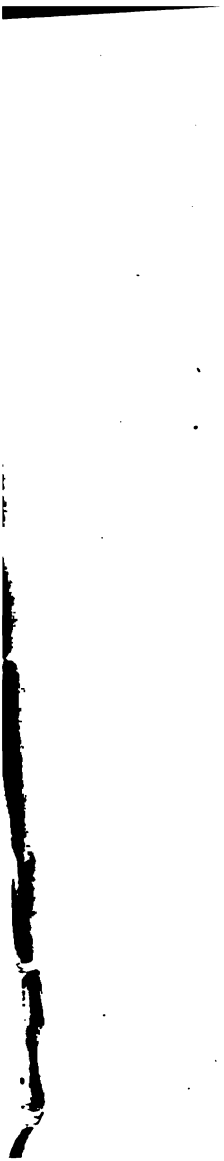
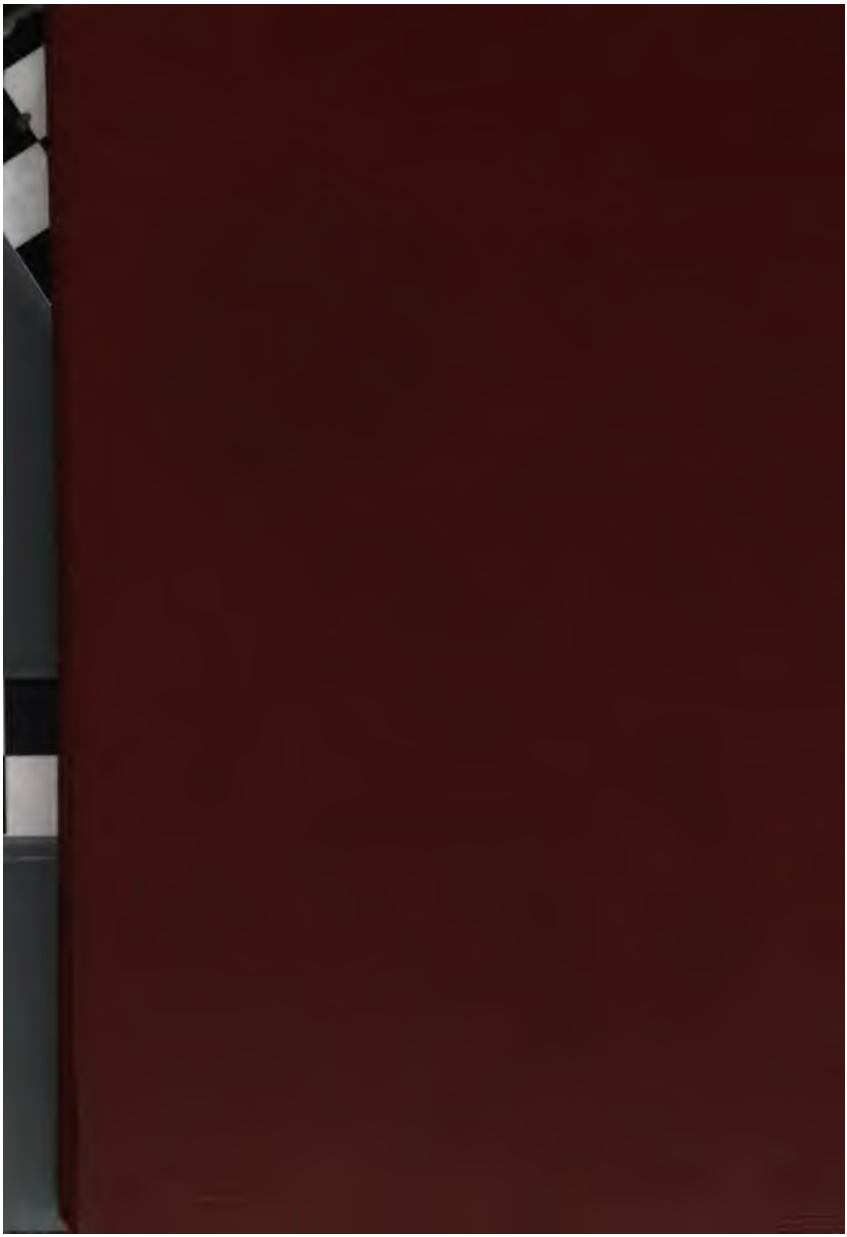
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